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The application of artificial intelligence for the detection of chorionic villi in the biopsy specimens

Detection of chorionic villi using computer vision

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Abstract
Aim: In this study, we aimed to find out the usefulness of artificial intelligence for the histological diagnosis of products of conception by identifying the chorionic villi in the tissue specimens.
Materials and Methods: A total of 400 anonymized digital images were acquired, which were divided into two groups. Group 1 included 200 images containing chorionic villi while Group 2 was comprised of 200 images of decidual tissue. Two variants of two deep learning computer vision algorithms VGG-16, VGG-19, and Resnet -18, Resnet -34 had been applied for the evaluation and analysis of the digital pathology image.
Results: The application of deep learning computer vision algorithms, VGG-16, VGG-19, Resnet-18, and Resnet-34 revealed the diagnostic accuracy of 95.3%, 99.4%, 98.1 %, 98.2% and F1-Score of 0.989, 0.989, 0.984 and 0.989 on test data respectively.
Discussion: The specimens of products of conception are quite frequently received for histopathological evaluation by the pathology laboratory. A careful histological examination is required for the identification of chorionic villi in the submitted specimens. The present study revealed that the application of artificial intelligence could be valuable assistance to the histopathologists for the microscopic examination of biopsy specimens. The diagnostic accuracy achieved in the present study is quite close to the reported figures for the diagnosis of lung and prostatic cancer with the help of deep learning in other series. The present study revealed that computer vision-based system may be an effective adjunct tool for the histopathological detection of chorionic villi.

Keywords
Chorionic villi; Deep learning; Computer vision; Resnet; VGG

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Introduction

One of the important causes of vaginal bleeding in females of the reproductive age group is retained products of conception (RPOCs) after the childbirth or miscarriage. Different modalities are used for the diagnosis of retained products of conception (RPOCs) which include assessment of clinical features, ultrasound, and histopathology. The clinical signs and symptoms of retained products of conception include bleeding per vagina, fever, and pain in the lower abdomen. Ultrasound is usually done to detect retained products of conception, which usually shows hyperechoic material and increased thickness of the endometrium [1, 2]. Histopathological evaluation for the diagnosis of retained products of conception is considered to be the gold standard of all. The histopathological examination is also required for the differentiation between the trophoblastic and non- trophoblastic tissue which cannot be done on the basis of clinical, sonographic, and intraprocedural criteria [3]. The retained products of conception are managed either medically or surgically [4, 5]. Medical management is usually given to women with no signs of infection, heavy bleeding or fever. While surgical management is usually performed in patients who show signs and symptoms of infection like fever, heavy bleeding, severe abdominal pain or suspected gestation trophoblastic disease. The majority of females who were admitted to the hospital due to miscarriage were in the gestational week of five to thirteen [6]. Surgical management includes traditional Evacuation and Curettage or hysteroscopic removal (morcellation or loop resection) [7]. After the uterine evacuation, the tissue should be examined histologically to rule out the possibility of any neoplasm or gestational trophoblastic disease [8]. The thorough microscopic evaluation of retained products of conception is quite time-consuming task as sometimes the tissue is abundant in amount. The mounting stress on histopathologists due to histological examination of a large number of glass slides maybe relieved to some extent by the application of artificial intelligence.

This study is aimed to find out the effectiveness of artificial intelligence for the histological diagnosis of products of conception by identifying the chorionic villi in the tissue specimens.

Material and Methods

Four hundred (400) anonymized digital images have been acquired from the anonymized glass slides stained with hematoxylin and eosin stain. The state-of-the- art two deep learning computer vision algorithms with two variations, VGG-16, VGG-19, Resnet-18 and Resnet -34 have been applied for the evaluation and analysis of digital pathology images. Due to the data limitation, transfer learning approach was applied; weights trained on ImageNet data set were downloaded and given as initial weights to the algorithms using FastAI library [9]. The 400 anonymized digital images have been split into two categories. There were 200 images of chorionic villi and this category was labeled as chorionic villi. The other category had 200 images of decidual tissues. These images have been reviewed by two histopathologists.

A random approach of FastAI API was used to load the data into train and test sets, to avoid the chances of selecting images of the same class been selected for mini-batch input, which could harm the performance of model validation in the training phase.

The entire dataset have been split into two sets. Eighty (80) % of the images were included in the training set. The testing set contained 20% of the total images. To increase the accuracy and F1-Score image, augmentation was done using default parameters of FastAI library. A 5-fold cross-validation was used to train the algorithms.

Results

A total of four hundred (400) anonymized digital images were collected. One group was composed of two hundred images (200), which contain chorionic villi and this group was labeled as chorionic villi. The other group had two hundred (200) images of decidual tissues only without any chorionic villi and this group was labeled as decidual tissue. Three hundred and twenty (320) images were chosen randomly from both groups (chorionic villi and decidual tissue) that is 80% of the total data set and employed for training data set. Whereas eighty (80) images were randomly chosen from both groups (chorionic villi and decidual tissue), which is 20% of the total data set employed in the test data set. Two deep learning computer vision algorithms with two variations, VGG-16, VGG- 19, Resnet-18, and Resnet-34 were used that revealed the accuracy of 95.3%, 99.4 %, 98.1 %, 98.2% and F1-Score of 0.989, 0.989, 0.984, and 0.989 respectively on test data set. The results are shown in Tables 1 and 2.

Table 1. Confusion Matrix of Train and Test Sets

Algorithm	Train				Test			
VGG -16	Actual	Decidual tissue	151	1	Actual	Decidual tissue	47	0
		Chorionic villi	1	167		Chorionic villi	1	32
			Decidual tissue	Chorionic villi			Decidual tissue	Chorionic villi
			Predicted				Predicted	
VGG -19	Actual	Decidual tissue	168	0	Actual	Decidual tissue	31	0
		Chorionic villi	2	150		Chorionic villi	0	49
			Decidual tissue	Chorionic villi			Decidual tissue	Chorionic villi
			Predicted				Predicted	
ResNet -18	Actual	Decidual tissue	161	2	Actual	Decidual tissue	36	0
		Chorionic villi	1	156		Chorionic villi	0	44
			Decidual tissue	Chorionic villi			Decidual tissue	Chorionic villi
			Predicted				Predicted	
ResNet -34	Actual	Decidual tissue	155	1	Actual	Decidual tissue	42	1
		Chorionic villi	1	163		Chorionic villi	0	37
			Decidual tissue	Chorionic villi			Decidual tissue	Chorionic villi
			Predicted				Predicted	

Table 2. Detailed dataset of test results

Algorithm	Precision	Recall	F-1 Score	Accuracy
VGG-16	0.99	0.99	0.989	95.3%
VGG-19	1.0	0.98	0.989	99.4%
ResNet-18	0.98	0.99	0.984	98.1%
ResNet-34	0.99	0.99	0.989	98.2%

Discussion

The results of the present study are very encouraging regarding the application of artificial intelligence for the histological diagnosis of products of conception. The retained products of conception may occur due to miscarriage or abortions. The miscarriage/abortions are associated with morbidity and mortality in women [10]. Miscarriages are also a risk factor of anemia in females [11].

The tissue specimens of miscarriage/abortion/products of conception are quite frequently received by the pathology laboratory for histopathological examination. A thorough microscopic assessment of slides is required for the identification of chorionic villi. Artificial intelligence may be applied to provide assistance to the histopathologists for the histological assessment of glass slides.

Artificial intelligence is making a significant contribution to the digital revolution. The artificial intelligence is trying to enhance the capabilities of computers so that the computer-based system can better do what humans are currently doing. The application of artificial intelligence will provide the capability to the system to learn and improve automatically from the experience and available data. The development of deep learning technology (a subset of artificial intelligence) has yielded markedly improvement in image analysis and recognition. The subset of deep learning is a convolutional neural network which has remarkably improved the image processing [12].

Makimoto H et al. published a study in which the performance of the convolutional neural network was better than clinicians for the accuracy in the diagnosis of myocardial infarction by analyzing the images of electrocardiogram [13]. In the present study, two deep learning computer vision algorithms with two variations VGG-16, VGG-19, Resnet-18, and Resnet-34 have been applied on the test data, which revealed the accuracy of 95.3%, 99.4%, 98.1 %, 98.2% respectively. The diagnostic accuracy of convolutional neural network architecture for the diagnosis of products of conception in the present study is quite close to the reported figures for the diagnosis of lung and prostatic cancer with deep learning [14,15]. The microscopic examination of glass slides by the anatomic pathologist for the histopathological diagnosis of malignant tumors is a labor- intensive and time- consuming process. Missing or non-visualization of a small area on the slide may lead to a lethal mistake in the diagnosis. Over the past century, this process has been practiced with minor modifications. This laborious job increases the chance of fatigability which raises the risk of human errors. There are possibilities of errors in the pathology laboratories which may have severe devastating effects in patient care [16]. The development of artificial intelligence applications for the assessment of biopsies will be a great help to the histopathologists in the current scenario of the rising trend in workload in the diagnostic laboratories. The limitation of the present study includes the limited availability of digital pathology images. Further studies on large data set are recommended.

Conclusion

The application of deep learning technology in the field of pathology for the histological diagnosis of chorionic villi in biopsy specimens is a very helpful tool.

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Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

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